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# *Directions of Development and Research Gaps in the Prediction of Bank Bankruptcy or Restructuring*

**Keywords:** bankruptcy prediction; cooperative banks; prediction models; restructuring

**JEL:** G01; G17; G21

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**Abstract**

**Theoretical background:** The analysis presented in the article is grounded in contemporary theories concerning the prediction of banking crises and the application of predictive models in the financial sector. Particular emphasis is placed on concepts related to big data, artificial intelligence, and machine learning, which are increasingly pivotal in financial stability analyses. The article references global models such as logit and random forests, highlighting their potential and limitations within the specific context of local conditions, particularly in the Polish banking market. Key gaps in the existing literature are identified, underscoring the necessity of developing models that incorporate macroeconomic variables and local regulatory frameworks, thereby enabling the adaptation of global tools to regional environments more effectively.
**Purpose of the article:** The article aims to analyze the emerging trends in bankruptcy and restructuring prediction models for banks and identify key research gaps in the context of the Polish banking market, comparing it to global benchmarks. It discusses the increasing role of big data, artificial intelligence, and machine learning in predicting banking crises and assesses their applicability to smaller economies like Poland. The study examines global prediction models, such as logit, random forests, and big data-driven approaches, emphasizing the need to adapt them to local economic conditions.

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**Research methods:** The study employs a comprehensive literature review methodology, critically evaluating existing predictive models and their applicability to the Polish banking market. A comparative analysis is conducted between global predictive models and local market conditions, with a focus on macroeconomic variables such as inflation, unemployment, and exchange rate volatility. The research also examines the challenges specific to Poland's banking sector, particularly cooperative banks, and explores the integration of advanced technologies, such as big data and artificial intelligence, to enhance predictive accuracy. The methodological approach encompasses critical analysis, document review, and comparative evaluations, supported by expert insights, to identify key research gaps and propose tailored solutions for smaller economies like Poland.
**Main findings:** The study identifies significant gaps in the application of global predictive models to the Polish banking sector, particularly with regard to the unique challenges posed by local economic conditions and regulatory frameworks. It highlights the necessity of developing tailored models that integrate macroeconomic variables specific to Poland, such as inflation and currency volatility, to improve the accuracy of predictions. The findings underscore the growing potential of advanced technologies, including big data and artificial intelligence, in enhancing early warning systems for banking crises. Additionally, the research provides a comparative perspective, demonstrating the need for greater alignment between global approaches and local market realities, especially for cooperative banks and smaller financial institutions operating within the Polish economy.

## Introduction

In recent years, the stability of the banking sector has become a critical concern not only for individual economies (NBP, 2024) but also for the global financial system (Chao et al., 2022; Le et al., 2023). Banking crises, such as the one in 2008, have highlighted the importance of early identification of risks to the banking sector that could lead to its destabilisation. In response to these challenges, both academic literature and banking practice have developed a range of predictive models aimed at forecasting bank failures and assessing restructuring risks. Models such as logit, random forests, artificial intelligence (AI), and big data-supported approaches have gained recognition as effective tools for predicting financial crises in developed markets, particularly in the United States, Western Europe, China, and India. These contemporary models increasingly incorporate emerging factors, such as non-financial information and ESG variables (environmental, social, and governance), as determinants of banking institutions' insolvency risk (Citterio, 2024).

Nevertheless, the application of these models in the context of smaller economies, such as Poland, faces specific challenges. Local macroeconomic conditions, market structure, and regulatory frameworks necessitate the adaptation of global predictive models to local circumstances (Olszak, 2014, pp. 7–26). Key variables such as inflation, unemployment, monetary policy, and exchange rate volatility significantly impact the stability of Polish banks, particularly cooperative banks operating within local financial markets (Kasiewicz & Rogowski, 2006, pp. 3–36). The development of modern technologies, such as big data, AI, and fintech, creates new opportunities for enhancing the prediction of bank failures (Zang, 2023).

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The objective of this article is to analyse current trends in bank failure prediction models, with a particular focus on big data technologies, and to compare their effectiveness across selected economies. An additional aim is to identify, through the conducted analysis, the most significant research gaps in the development of predictive models tailored to smaller or local markets, such as Poland.

Key research gaps have been identified, highlighting the need to develop models that are better suited to the specific characteristics of the Polish banking market. Additionally, the role of big data technologies in supporting the banking sector in crisis forecasting and risk management has been discussed. Predicting bank failures is crucial not only for the decision-making processes within banks but also for addressing broader economic challenges at the national level. Poor or misguided business decisions made by banks can have catastrophic consequences, both domestically and globally (Shah et al., 2022, pp. 807–812).

## Literature review

### Current trends in bank failure and restructuring prediction models

In recent years, the rapid development of information technologies, particularly in the areas of big data and AI, has significantly influenced the evolution of predictive models used in the banking sector. These models, based on advanced data processing techniques such as machine learning algorithms, have become increasingly precise and flexible in forecasting risks of bank failures. Petropoulos et al. (2020, pp. 1092–1113) emphasise in their study that the application of algorithms such as Support Vector Machines (SVM), decision trees, and random forests enhances the effectiveness of financial crisis predictions. These models utilise a wide range of financial variables, encompassing both traditional financial indicators and more advanced market data, such as market volatility and macroeconomic indices. Zhao et al. (2009, pp. 2633–2644) note that modern approaches to constructing predictive models, based on deep learning algorithms, enable the identification of hidden patterns within large datasets, thereby significantly improving the accuracy of bank failure forecasting.

In the context of the 2008–2009 financial crisis, many models based on logistic regression or traditional financial analyses, such as the CAMELS model, proved ineffective in forecasting risks associated with the insolvency of financial institutions. These shortcomings prompted researchers to explore new solutions, including methods utilising non-linear data and advanced AI tools. Kristóf and Virág (2022, p. 101644) emphasise that AI-driven models, such as neural networks and multi-agent systems, are becoming the standard in predicting insolvency risks, particularly in larger economies like the United States and the European Union.

The development of AI tools, particularly in the design and performance of algorithms capable of processing and analysing increasingly large datasets, highlights

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that machine learning algorithms, such as gradient boosting decision trees, random forests, and non-recurrent multilayer neural networks, are the most effective (and often the first choice) for bankruptcy prediction. Preliminary hypotheses have been formulated based on practitioners' insights regarding the utility of various machine learning and AI algorithms in forecasting corporate insolvencies (Wyrobek, 2018, pp. 41–60).

Considering the growing complexity of predictive models, it is increasingly important to address ethical and regulatory aspects associated with the use of big data and AI technologies in the banking sector. As financial institutions increasingly rely on algorithms for credit decision-making and risk assessment, concerns have arisen regarding the transparency of these processes and the potential for customer discrimination. Furthermore, studies indicate that the lack of appropriate regulations could lead to unpredictable consequences for market stability, as highlighted by comparative analyses of different banking systems worldwide (Olszak, 2014, pp. 7–26). Therefore, it is essential to develop legal frameworks that not only foster innovation but also ensure consumer protection and maintain equilibrium in an ever-evolving financial environment (Kasiewicz & Rogowski, 2006, pp. 3–36).

**Gaps in the literature on bankruptcy prediction in smaller markets, including Poland**

Despite significant advancements in bank failure prediction, there remain substantial gaps in research concerning smaller economies, such as Poland. Models developed for advanced financial markets often fail to account for the specificities of local regulations, market structure, operational characteristics of banks, and data availability, all of which have a critical impact on the stability of cooperative banks and smaller commercial banks (Ustawa z dnia 29 sierpnia 1997 r.; Ustawa z dnia 7 grudnia 2000 r.; Rozporządzenie…).

Meyer and Pifer (1970, pp. 858–868) highlighted that many predictive models operate under the assumption that financial markets function similarly, regardless of their size and structure. However, in smaller economies like Poland, local factors such as real estate market dynamics and access to capital can significantly influence the financial stability of banks. Additionally, limited access to advanced technologies and analytical tools in smaller financial institutions means that many are unable to implement modern predictive models based on big data or AI.

Research on the Polish banking market reveals a significant gap: the lack of empirical studies addressing the specific characteristics of local cooperative banks and their unique operational structures. Günönü et al. (2023, pp. 1–16) highlight the absence of predictive models tailored to specific conditions such as local legal regulations, ownership structures, and dependencies on local credit institutions. It can be argued that the lack of data on detailed financial and operational indicators, including those of cooperative banks, constitutes a major obstacle to developing accurate bankruptcy prediction models (Olszak, 2014, pp. 7–26).

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Additionally, in the context of increasing competition in the banking market and rapid technological advancements, understanding the impact of fintechs on traditional bankruptcy prediction models becomes essential. Fintech companies, which often leverage advanced analytical algorithms and access to large datasets, can provide innovative approaches to risk assessment and financial stability for smaller institutions. In Poland, where the banking sector is highly diverse, integrating fintech tools could support the development of more accurate predictive models that take into account local market conditions and macroeconomic variables. Moreover, collaboration between banks and technology startups could facilitate the exchange of knowledge and expertise, which is crucial for effectively implementing modern analytical solutions within the Polish banking system.

**Comparative analysis of predictive models used in different countries**

A comparative analysis of predictive models employed across various countries reveals significant differences in their approaches to forecasting bank failures. In advanced economies, such as the United States and the European Union, predictive models are often highly sophisticated, leveraging cutting-edge analytical technologies. Stuhr and Van Wicklen (1974, pp. 233–238) describe models such as CAMELS, widely implemented in the United States, which are built upon regular financial reporting that provides detailed information on liquidity, asset quality, and bank profitability. These models demonstrate their efficacy in developed markets, where data availability and quality are consistently robust.

In smaller economies, such as Poland, these models often fail to deliver accurate results due to a lack of access to critical data and differences in the structure of capital markets. Chawla et al. (2002, pp. 321–357) suggest that incorporating local variables, such as macroeconomic indicators and data on risks in local real estate markets, could enhance the accuracy of bankruptcy forecasting in smaller countries. In Poland, the inclusion of such variables in predictive models could significantly improve their effectiveness, particularly in the context of cooperative banks, which are more vulnerable to local economic crises.

One of the research observations indicates that rigorous internal risk assessments and external factors, such as regulatory interventions, contribute to maintaining the resilience of banks in the face of global economic crises. Studies suggest that banks can benefit from employing predictive models for bankruptcy analysis as part of their strategy development processes (Purwanti et al., 2024, pp. 4428–4440).

In the context of the increasing complexity of predictive models and their potential adaptation to the Polish banking market, it is essential to consider the importance of education and training for financial sector employees. Enhanced knowledge of big data technologies and AI could facilitate the more effective application of these tools in practice, which is particularly critical in the face of dynamic market changes. Furthermore, collaboration between academic institutions, financial organisations,

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and regulatory bodies could establish a platform for exchanging experiences and innovative ideas, enabling a more rapid adaptation of predictive models to local economic conditions. It is worth noting that such an approach would not only improve the efficiency of bankruptcy forecasting but also strengthen the overall stability of the Polish banking system, which is crucial for protecting the interests of both consumers and investors.

**The role of big data in bank risk analysis**

The utilisation of big data technologies in the financial sector has become a pivotal element in the development of modern models for predicting bank insolvency risk. Big data refers to vast datasets that can originate from diverse sources, including financial, demographic, market-related information, and consumer behaviour data. Petropoulos et al. (2020, pp. 1092–1113) highlight that banks are increasingly leveraging advanced tools for analysing large datasets to monitor credit risk and assess the financial standing of their clients.

As banks increasingly rely on big data technologies, it becomes critical to address the challenges associated with data management and ensuring data security. In the context of rising cyber threats, financial institutions must not only invest in advanced analytical systems but also develop robust data protection strategies to mitigate potential financial and reputational losses. Moreover, integrating fintech tools with traditional banking models presents new opportunities for innovation in risk analysis. However, this requires well-coordinated collaboration among various financial market stakeholders to effectively combine advanced technologies with local market conditions.

One of the primary applications of big data in banking is real-time risk monitoring. In developed markets, such as the United States and Western Europe, banks utilise big data technologies to continuously track credit risk, incorporating both macroeconomic and microeconomic variables. In Poland, particularly in the context of cooperative banks, big data could become a critical tool for monitoring local variables such as inflation, unemployment, and real estate market dynamics.

**Predicting banking crises using big data**

Predictive models based on big data possess the ability to identify hidden patterns that may signal future financial threats. Breiman (2001, pp. 5–32) and Chawla et al. (2002, pp. 321–357) have introduced innovative approaches to data analysis, such as random forests and SMOTE, which enhance the identification of risk. These models are particularly effective in analysing non-linear relationships and detecting anomalies, which can indicate impending financial crises.

In Poland, the implementation of these technologies could assist banks in detecting risks associated with local market crises more rapidly. Given the specific char-

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acteristics of the Polish market, adopting such tools could enhance the effectiveness of predictive models and facilitate improved risk management, which is particularly critical for smaller banks.

#### Challenges associated with big data implementation

The implementation of big data in the banking sector, particularly in Poland, faces several barriers. One of the main challenges is access to high-quality data and the requisite technological infrastructure. Zhao et al. (2009, pp. 2633–2644) highlight that the effectiveness of predictive models based on big data heavily relies on the quality of the available data. Banks, especially smaller institutions, must invest in technology and enhance collaboration with governmental and private entities to collect more reliable data.

Another significant challenge involves data protection regulations, such as the General Data Protection Regulation (GDPR), which impose strict requirements on banks regarding the processing of customer data. Purwanti et al. (2024, pp. 4428–4440) emphasize that privacy concerns must be a priority, especially when implementing big data technologies in financial institutions. Compliance with these regulations necessitates robust data governance frameworks and may limit the extent to which customer data can be utilized for predictive modeling.

#### The future of big data in bank failure prediction

The future of big data technology in bank failure prediction appears promising, particularly in the context of smaller markets such as Poland. Leveraging advanced data analysis tools could enable Polish banks to more effectively monitor local variables, such as household debt levels, real estate market volatility, and unemployment rates. Günönü et al. (2023, pp. 1–16) suggest that implementing big data in smaller banks could significantly enhance their ability to forecast crises and undertake appropriate preventive measures.

From a global perspective, big data is emerging as one of the most critical tools in bank risk management. Poland has the opportunity to join the group of countries that effectively implement these technologies within their financial institutions.

## Research methods

The research objectives outlined in the "Introduction" section dictate the following stages of the study:

– **analysis of general trends in bank failure and restructuring prediction models**, with a focus on models that leverage advanced data processing techniques and demonstrate the highest efficiency. This stage also includes examining the poten-

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tial adaptation of existing models, commonly applied in highly developed economies, to smaller economies such as Poland;

– **examination of existing and utilised bank failure prediction models**, with an emphasis on adapting models designed for developed economies to the conditions of smaller economies;

– **evaluation of the potential for utilising big data technologies** in the development of modern models for predicting bank failure risk;

– **identification of research gaps in the development of predictive models for smaller or local markets (e.g. Poland)** and the formulation of general research hypotheses for further investigation, accompanied by their justification.

For the purposes of this article, exploratory research was conducted, including interpretative studies (highlighting the diversity of predictive models), analytical research, and comparative analyses (also involving comparisons of these models). This research provided not only factual insights into bank failure prediction models but also a deeper understanding of the various factors influencing their development (Burnewicz, 2021). Part of the planned analyses aligns with the characteristics of theoretical research. This includes the organisation and supplementation of existing perspectives, as well as the intuitive conceptualisation of new solutions based on a critical review of the academic literature on bank failure prediction models (Bowen, 2009, pp. 27–40). It is important to emphasise that a defining feature of theoretical research is its capacity to formulate new scientific hypotheses, thereby setting new directions for future studies (Burnewicz, 2021, p. 317).

The research employed critical literature analysis, document analysis, comparative analysis, and direct observations, combined with the author's expert knowledge (Bowen, 2009, pp. 27–40).

## Results

### Research proposals (identification of research gaps in the development of predictive models for smaller local markets, such as Poland)

In light of the literature review and identified research gaps, one of the key directions for future studies is the development of predictive models that account for the specific risks characteristic of smaller economies, such as Poland. Existing models, often utilised in large financial markets such as the United States, Western Europe, China, and India, lack the flexibility needed to reflect the unique conditions of smaller markets. These models inadequately address the specificity of cooperative banks and the influence of local regulations, which represents a significant limitation in their application (Ustawa z dnia 29 sierpnia 1997 r.; Ustawa z dnia 7 grudnia 2000 r.; Rozporządzenie…).

Purwanti et al. (2024) suggest that models applied in smaller economies should be tailored to local conditions, including the banking market structure, regulatory

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specifics, and capital access levels. As an economy with a developing banking sector, Poland requires models capable of accounting for the impact of local regulations, such as the fiscal and monetary policies of the National Bank of Poland, as well as local economic conditions like the dynamics of the real estate sector.

In the development of predictive models, it is equally important to consider the role of collaboration between the public and private sectors in Poland. Joint initiatives could facilitate improved data collection and the creation of more flexible models tailored to local conditions. For instance, integrating fintech resources with traditional financial institutions could provide cooperative banks with access to modern analytical tools, enabling more effective risk monitoring and crisis forecasting. Additionally, the involvement of universities in researching the specificities of the Polish banking market, in collaboration with financial market regulatory bodies, could lead to the creation of innovative solutions that address the unique needs of smaller economies. Such advancements are crucial for ensuring the stability of the entire financial system.

**First research proposal: Identification of predictive variables reflecting the specificities of local markets**

The introduction of economic indicators specific to the local operational nature of cooperative banks into early warning systems could improve the effectiveness of bankruptcy forecasting for Polish banks. Research should focus on integrating these indicators into existing predictive models. The development of predictive models should also incorporate information derived from the activities of supervisory authorities (KNF, BFG, NBP) and risk assessments provided by rating agencies, which could enhance the accuracy of bankruptcy risk forecasting for banks in Poland.

An essential aspect of future research on bank failure prediction is the inclusion of new predictive variables that better reflect the specificities of the Polish market. For instance, one of the key factors that could significantly impact the stability of Polish banks is the dynamics of the real estate market. Günönü et al. (2023, pp. 1–16) highlight that in countries where the real estate market plays a critical role in the economy, variables related to property values and mortgage debt levels should be incorporated into predictive models.

In Poland, where the real estate market is experiencing dynamic growth, variables such as changes in property prices, the number of mortgage loans granted, household debt levels, and financial market conditions in the context of decisions made by young bank customers (Czechowska & Kuśmierska, 2022, pp. 8–27) can have a decisive impact on the financial stability of banks. Additionally, the growing number of non-performing loans (NPLs) poses a significant risk to the Polish banking sector. Chawla et al. (2002, pp. 321–357) emphasise that incorporating variables related to NPLs and credit risk into predictive models can substantially improve their accuracy.

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In the context of dynamic changes in the real estate market, which may affect the stability of banks in Poland, the significance of market sentiment analysis as a novel predictive tool should also be considered. Research indicates that consumer and investor sentiment has a substantial impact on decisions related to property purchases and the granting of mortgage loans, which in turn can influence the risk of financial institution insolvency. Integrating sentiment data with traditional macroeconomic indicators could create more comprehensive forecasting models that account for psychological variables often overlooked in classical approaches. Furthermore, the use of text analysis technologies to monitor public opinion in social media and press reports could provide valuable insights into anticipated real estate market trends. Such information is crucial for effective risk management by Polish banks.

**Second research proposal/gap: The role of fintechs in the operations of local banking markets**

Predictive models for the Polish banking market should incorporate the activities of fintechs. Research in this area could contribute to the creation of more accurate analytical tools that better reflect the realities of Poland's financial market.

The development of financial technologies (fintech) is increasingly influencing the functioning of the banking sector, representing another research area requiring particular attention. In Poland, as in other countries, fintechs are gaining prominence as alternatives to traditional banks, offering innovative financial services such as mobile payment platforms, peer-to-peer (P2P) lending, and crowdfunding. Petropoulos et al. (2020, pp. 1092–1113) point out that fintechs can impact the financial stability of banks, both by increasing competition and by providing new technological solutions that can be integrated into predictive models.

Kristóf and Virág (2022, p. 101644) suggest that the integration of fintechs with the traditional banking sector, combined with the use of technologies such as big data and AI for risk analysis, could significantly enhance the accuracy of predictive models. Consequently, research on the impact of fintechs on the financial stability of Poland's banking sector is becoming increasingly important.

At the same time, understanding how fintech development affects regulation and oversight in the banking sector is critical, as it may lead to new challenges for financial stability. As fintechs become an integral part of the financial ecosystem, it is necessary to adapt existing regulatory frameworks to accommodate innovative business models and address the risks associated with their operations. Regulations should be flexible enough to foster continued innovation while remaining robust enough to protect consumers from potential misconduct. Moreover, collaboration between traditional institutions and fintechs could benefit both parties, contributing to improved risk management and enhanced operational efficiency – key factors in the context of increasing competition in the banking market.

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**Third research proposal/gap: Identification and integration of local economic indicators into bank failure prediction models**

Research on the impact of fintechs on the stability of Poland's banking sector should focus on integrating modern technologies with traditional predictive models. An analysis of how fintechs influence the risk of bank failures and restructurings could provide valuable insights into future trends in the Polish financial sector (Gasz, 2014, pp. 45–60).

Studies on Poland's banking market and post-crisis experiences consistently offer new recommendations for banks and regulatory authorities. These emphasize the importance of fully implementing prudential measures outlined by the Basel Committee and applying them to all banks, not only those operating internationally. Past disruptions have highlighted the significance of effective supervision, robust risk management within banks, improved regulation of interest rate risk management, and consistent application of AT1 instruments globally. These disturbances have also reignited the debate over the extent of deposit guarantees and the mechanisms of compulsory bank restructuring in the sector (Zygierewicz, 2024).

One of the key directions for future research is the integration of local economic indicators into bank failure prediction models. Zhao et al. (2009, pp. 2633–2644) stress that early warning systems incorporating local economic indicators, such as unemployment rates, labour market dynamics, and market volatility, can significantly enhance the accuracy of bankruptcy risk forecasting.

In Poland, where cooperative banks and smaller commercial banks are closely tied to local economies, the introduction of local indicators could improve risk monitoring. Specifically, incorporating variables related to local labour market dynamics, the financial health of local businesses, and regional fiscal policies could contribute to the development of more precise bank failure prediction models.

**Potential hypotheses**

Based on the literature review and the findings discussed in the previous chapters, several research hypotheses can be formulated, providing a foundation for future studies on bank failure prediction and restructuring, particularly in the context of the Polish market.

Table 1 presents a concise summary and highlights areas requiring further research and analysis within the subject matter, aiming to identify research gaps and enable a deeper investigation of the indicated areas.

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**Table 1.** Research gaps and hypotheses in bank failure prediction identified from source articles

| Research gap | Description of the gap | Scientific source | Related hypothesis |
|---|---|---|---|
| Lack of models for smaller economies | Predictive models primarily developed for large markets, lacking adaptation or development for smaller economies such as Poland | (Kasiewicz & Rogowski, 2006, pp. 3–36; Meyer & Pifer, 1970, pp. 853–868; Purwanti et al., 2024, pp. 4428–4440) | H1: Global predictive bank models do not account for the specific characteristics of smaller banking markets, such as Poland |
| Insufficient consideration of local variables | Global models do not account for specific macroeconomic indicators relevant to smaller markets | (Günönü et al., 2023, pp. 1–16; Kristóf & Virág, 2022, p. 101644) | H2: The inclusion of local macroeconomic indicators improves the accuracy of forecasts in Poland |
| Limited research on AI and big data technologies | Challenges in adapting advanced analytical technologies (AI, big data) in smaller banking institutions | (Petropoulos et al., 2020, pp. 1092–1113; Purwanti et al., 2024, pp. 4428–4440; Zhao et al., 2009, pp. 2633–2644) | H3: Fintech technologies can serve as an alternative to traditional predictive models in the Polish banking sector |
| Lack of empirical models for local cooperative banks | Absence of models tailored to the specificity of local cooperative banks and their operational structures | (Günönü et al., 2023, pp. 1–16; Kasiewicz & Rogowski, 2006, pp. 3–36; Meyer & Pifer, 1970, pp. 853–868) | H4: Polish cooperative banks are more vulnerable to local economic crises than commercial banks |
| Insufficient research on the impact of fintech | Lack of studies on the impact of fintech on the stability of smaller banking markets and their integration with traditional predictive models | (Kristóf & Virág, 2022, p. 101644; Petropoulos et al., 2020, pp. 1092–1113) | H3: Fintech technologies can serve as an alternative to traditional predictive models in the Polish banking sector |

Source: Author's own study.

**Hypothesis 1: Bank failure prediction models do not account for the specific characteristics of smaller banking markets, such as Poland.** Bank failure prediction models, such as CAMELS, random forests, or neural networks, rely on data derived from developed markets, including the United States, Western European countries, China, and India. As a result, these models fail to account for the specific conditions prevailing in smaller economies, such as Poland. In these countries, banks often operate within local structures that differ significantly from large banking institutions in developed markets.

Smaller cooperative banks in Poland may be more susceptible to risks associated with local conditions, such as real estate market dynamics, credit availability, or adaptation to changing legal regulations. Meyer and Pifer (1970, pp. 853–868) and Günönü et al. (2023, pp. 1–16) suggest that predictive models based on data from developed economies may inaccurately assess the risk of bankruptcy in smaller markets, leading to an underestimation of potential threats.

**Hypothesis 2: The inclusion of local economic indicators and qualitative data from the banking sector improves the accuracy of restructuring forecasts in Poland.** Integrating local economic indicators such as unemployment rates, real estate market dynamics, levels of non-performing loans (NPLs), inflation, and interest rates on banking products and services (Jankowska, 2023, pp. 13–27) can

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significantly enhance the effectiveness of predictive models for the Polish banking sector. Banks operating in local markets are often more vulnerable to local economic fluctuations, which traditional predictive models fail to fully account for (Kristóf & Virág, 2022, p. 101644).

Incorporating variables such as real estate market dynamics, the number of mortgage loans granted, and unemployment rates into predictive models could provide more accurate forecasts for bank restructuring. Zhao et al. (2009, pp. 2633–2644) suggest that including local variables can substantially improve the prediction of financial crises in smaller economies, such as Poland.

**Hypothesis 3: Fintech technologies can serve as an alternative to traditional predictive models in the Polish banking sector.** The development of financial technologies (fintech), such as big data, AI, and blockchain, could serve as an alternative to traditional bank failure prediction models in Poland. Fintechs can provide advanced analytical tools that better reflect the specificities of local markets and the evolving economic conditions (Petropoulos et al., 2020, pp. 1092–1113).

The application of fintech in bank failure prediction could contribute to faster detection of financial threats and improved efficiency of early warning systems. Chawla et al. (2002, pp. 321–357) highlight that integrating fintech with traditional predictive models can enhance the banking sector's ability to respond to sudden economic changes.

**Hypothesis 4: Polish cooperative banks are more vulnerable to economic shock crises than commercial banks.** Cooperative banks, operating within smaller local communities, are more susceptible to economic downturns that significantly impact the functioning of institutions at the local level. The ownership structure of cooperative banks and their limited access to international capital markets make their financial stability more dependent on local economic conditions (Stuhr & Van Wicklen, 1974, pp. 233–238).

Developing and implementing predictive models that account for the specific operational characteristics of cooperative banks within institutional protection schemes could enhance risk monitoring in cooperative banks and support the effective application of principles governing such systems.

## Conclusions

The article analyses selected models for predicting bank failures, encompassing both traditional methods, such as logit, and modern tools based on big data and AI. It highlights the growing importance of advanced technologies, such as fintech and big data, which enable enhanced monitoring of banking risk, particularly in the context of dynamically changing macroeconomic variables. Simultaneously, the article emphasises the necessity of adapting thee tools to local conditions, such as those in Poland.

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By analysing data from various sources, the article demonstrates that while global predictive models are effective in large markets, their adaptation to smaller economies, like Poland, requires consideration of specific variables. Factors such as inflation, unemployment, monetary policy, exchange rate volatility, supervisory evaluations, and external ratings significantly influence the stability of Polish banks, necessitating the development of models that incorporate these elements. Additionally, the article identifies challenges faced by the Polish banking sector, including access to data and technological infrastructure, which may hinder the full utilisation of big data's potential.

The article also underscores that a key direction for future research should be the development of predictive tools that not only integrate advanced technologies but are also tailored to local conditions and have access to all necessary data. Only then can Polish banks effectively manage bankruptcy risk, and predictive models support their financial stability in the long term.

The integration of big data as a core component of predictive models offers new opportunities for the banking sector, which, if appropriately harnessed, could significantly improve the accuracy of financial risk forecasting.

In conclusion, the article identifies significant gaps in existing research, stressing the need for models that are better adapted to the specific characteristics of the Polish banking market. Furthermore, it highlights the potential of big data technologies in supporting the banking sector in crisis forecasting and effective risk management.

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